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Comparative study of *Gymnocephalus cernuus* (Linnaeus, 1758) and *G. baloni* Holcik & Hensel, 1974 (Pisces, Percidae)

by
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Abstract: In the comparative study of *Gymnocephalus cernuus* and *G. baloni* we searched for differences in growth, habitat and feeding between the two species in support of their distinctness. Significant differences were found in both habitat and feeding, whereas growth was more or less similar. *G. baloni* is bound to hiding places located in flowing water. In vegetative periods it occurs solitary and in generative in pairs. *G. cernuus* lives in shoals in the whole season, occurring mostly in the open, still parts of waters near to the bottom. The food of the two ruffe species mostly consists of the characteristic macroinvertebrates of their habitat. The body pattern, the number of opercular spines and the cut on the membrane between AI and AII were found to be the most useful characters in identification.
Key words: Pisces: Percidae: *Gymnocephalus cernuus*, *Gymnocephalus baloni*; morphology, habitat, growth, feeding

Introduction

In 1974, Holcik and Hensel described a new species of percid fish, *Gymnocephalus baloni*, from the Slovakian section of the Danube. According to the first record, this species has been treated in the literature and scientific collections as conspecific with *G. cernuus*, which it greatly resembles. Although no publication is known to us actually questioning the validity of *G. baloni*, its specific distinction is not definitely accepted despite the 20 years that have passed since then.

The studies described herein were conducted in order to clarify the distinctness of the two species. Based on the original morphological separation, we examined whether any ecological difference could be found between the two species, and if these corresponded with their separation.

Material and methods

173 specimens of *G. baloni* and 172 specimens of *G. cernuus* collected between 1989 and 1993 formed the basis of our investigations. In both cases, studied individuals originated from two different regions of the Hungarian Danube section, i.e. the Ásvány branch system in the Szigetköz area (1823-1820 rkm) and the main arm at Budapest-Háros (1635-1634 rkm), respectively.

Samples were taken from possibly all existing water velocities and habitats. For collecting, we used an electric fishing machine, lift-nets and the hook-on-line method. In sampling with hook-on-line, fly larvae and Oligochaeta served as bait. Specimens collected were fixed in 10% formalin at the site of collection, and were subsequently transformed to a 40% solution of isopropyl alcohol for definite

storage. We investigated the differences in morphology, habitat use, food composition and growth. Observations made in the field are also added.

4 counts and 36 morphometric measurements (percent ratios of body length, head length and AII-length) were selected as a basis for the morphological studies (for measuring points see Berinkey 1966). M, m (SE) and s (SD) were calculated for all parameters. The differences were expressed in coefficient of difference (CD) (Mayr 1969) and Student's t-test.

The comparison of habitats was made on the basis of studies of bottom substrate quality, and the presence or absence of hiding places performed at the collecting site of each specimen recovered. The measurements of flow velocity were taken with modified Zhestovskiy type (GR-21M) measuring instrument primarily at Háros, as measuring the velocity of water oozing through the rock-fills in the Szigetköz area proved impossible, and the water was immobile during the period October 1992 – July 1993. Resulting parameters were given at each species as a frequency of occurrence, and were evaluated with a χ^2-test.

Food composition was determined by investigating stomach contents. The basis of our research was formed by 75 specimens of *G. baloni* (46.2-127.7 mm standard length) and 86 specimens of *G. cernuus* (61.0-137.5 mm of standard length), collected in 1993. Food composition was given as a percental value of the number of individual prey groups. Diversity of food was expressed by Shannon-Wiener index (D). By comparison, similarity index – modified Sorensen-index (C_N) (see Southwood 1984) and χ^2-test were used.

Growth of fish (133 specimens of *G. baloni* and 95 specimens of *G. cernuus*) was back-counted on the basis of their age determined from scale ring composition. For describing it, we used Bertalanffy's growth model. Body length/body mass relations were also expressed (see Ricker 1975, Bagenal 1978). Student's t-test was performed to compare the results.

Results

Morphology

The results of our morphological comparisons conducted on *G. baloni* and *G. cernuus* are shown in Tables 1 and 2. Characters for separating the two forms given by other authors were useful on various levels of our investigations. In the following, we will attempt to compare these and our studies.

1. Body pattern consists of:
   * irregularly arranged dark dots on the body = *G. cernuus*
   * 4 to 6 dark vertical bands on the side of the body = *G. baloni*

   (after Holcik & Hensel 1974, Botta *et al.* 1984, Sivkov 1985, Pintér 1989).
   According to our observations, it can be different in some occasions. For instance, in the breeding season some *G. baloni* males lose their colours, and their bands disappear, whereas it remains conspicuous in females. The same can be seen during occasional high water levels in both sexes.
2. The angle between the soft portion of the dorsal fin and the lateral line on the caudal peduncle is:
   * perpendicular = *G. baloni*
   * acute = *G. cernuus*

   (after Holcik & Hensel 1974, Botta *et al.* 1984, Sivkov 1985, Pintér 1989).
   This characteristic is useful when separating specimens with undamaged pattern, whereas it is often invisible in damaged individuals.

Table 1. The morphological comparison of *Gymnocephalus baloni* and *G. cernuus*, collected from the Danube at Háros (Budapest) in 1993.

	Gymnocephalus baloni Háros (n=30)		*Gymnocephalus cernuus* Háros (n=30)				
	M ± m	s	M ± m	s	t	p	CD
Standard length (mm)	97.53 ± 1.88	10.27	84.91 ± 2.79	15.26	3.76	0.001	0.49
Spines in D	14.60 ± 0.10	0.56	13.63 ± 0.13	0.72	5.80	0.001	*0.75*
Soft rays in D	11.53 ± 0.16	0.90	12.30 ± 0.12	0.65	3.78	0.001	0.49
Spines in A	2.00 ± 0.00	0.00	2.00 ± 0.00	0.00	-	-	-
Soft rays in A	5.73 ± 0.11	0.58	5.00 ± 0.10	0.53	5.12	0.001	0.66
In % of Standard length							
Head length	31.49 ± 0.32	1.75	31.73 ± 0.33	1.78	0.53	-	0.07
Body depth	31.15 ± 0.27	1.49	27.22 ± 0.23	1.24	11.10	0.001	**1.44**
Caudal peduncle depth	8.24 ± 0.09	0.50	8.23 ± 0.11	0.63	0.07	-	0.01
Body width	20.52 ± 0.41	2.27	17.74 ± 0.27	1.51	5.59	0.001	*0.74*
Caudal peduncle width	4.23 ± 0.09	0.50	4.87 ± 0.08	0.41	5.43	0.001	*0.70*
Predorsal distance	31.37 ± 0.27	1.48	31.76 ± 0.33	1.81	0.92	-	0.12
Postdorsal distance	16.24 ± 0.37	2.05	17.93 ± 0.38	2.11	3.15	0.01	0.41
Preventral distance	36.65 ± 0.43	2.37	34.35 ± 0.29	1.57	4.44	0.001	0.58
Preanal distance	69.14 ± 0.40	2.18	67.51 ± 0.49	2.69	2.56	0.02	0.33
Distance P-V	4.49 ± 0.26	1.44	2.59 ± 0.24	1.33	5.32	0.001	*0.69*
Distance V-A	32.48 ± 0.44	2.41	33.16 ± 0.49	2.67	1.03	-	0.13
Base of A to anus	6.87 ± 0.26	1.45	6.93 ± 0.31	1.72	0.15	-	0.02
Caudal peduncle length	20.15 ± 0.37	2.03	23.14 ± 0.42	2.28	5.38	0.001	*0.70*
Length of spinous D	39.60 ± 0.43	2.37	35.18 ± 0.52	2.85	6.53	0.001	*0.85*
Length of soft D	12.79 ± 0.39	2.13	15.13 ± 0.37	2.03	4.35	0.001	0.56
Depth of spinous D	18.80 ± 0.32	1.73	19.90 ± 0.24	1.32	2.77	0.01	0.36
Depth of soft D	16.44 ± 0.26	1.42	15.44 ± 0.32	1.74	2.43	0.02	0.32
Length of A	10.71 ± 0.27	1.46	9.34 ± 0.45	2.49	2.60	0.02	0.35
Depth of AI	14.72 ± 0.22	1.21	15.72 ± 0.30	1.62	2.72	0.01	0.35
Depth of AII	14.30 ± 0.21	1.17	14.11 ± 0.21	1.13	0.65	-	0.08
Length of V	21.40 ± 0.17	0.95	22.56 ± 0.26	1.40	3.75	0.001	0.49
Length of P	20.42 ± 0.24	1.34	22.21 ± 0.33	1.80	4.38	0.001	0.57
Length of C	17.18 ± 0.30	1.67	18.52 ± 0.41	2.22	2.63	0.02	0.34
Diameter of DI	1.13 ± 0.03	0.15	1.08 ± 0.05	0.25	1.07	-	0.14
Diameter of AI	1.99 ± 0.04	0.24	1.77 ± 0.06	0.31	3.10	0.01	0.40
Diameter of VI	1.16 ± 0.02	0.13	0.93 ± 0.02	0.12	7.17	0.001	*0.93*
Length of VI	12.36 ± 0.22	1.23	12.64 ± 0.21	1.15	0.92	-	0.12
Length of V's base	5.63 ± 0.12	0.63	4.77 ± 0.09	0.50	5.85	0.001	*0.76*
Length of P's base	6.01 ± 0.09	0.50	5.16 ± 0.09	0.49	6.72	0.001	*0.87*
In % of Head length							
Head depth	73.02 ± 1.06	5.83	63.96 ± 0.75	4.10	6.96	0.001	*0.91*
Head depth at eye	58.41 ± 0.54	2.96	55.57 ± 0.78	4.25	3.00	0.01	0.39
Head width	57.14 ± 0.52	2.85	50.51 ± 0.70	3.86	7.57	0.001	*0.99*
Diameter of eye	28.26 ± 0.43	2.35	29.55 ± 0.45	2.48	2.07	0.05	0.27
Length of upper jaw	20.52 ± 0.64	3.48	19.65 ± 0.64	3.50	0.97	-	0.13
Mouth width	39.42 ± 0.42	2.29	33.40 ± 0.44	2.41	9.92	0.001	**1.28**
In % of AII's length							
Depth of the cut in the membrane between AI and AII	40.93 ± 1.50	8.21	12.61 ± 1.41	7.74	13.75	0.001	**1.78**

Table 2. The morphological comparison of *Gymnocephalus baloni* and *G. cernuus*, collected from the Danube in the Szigetköz side-branch system in 1993.

	Gymnocephalus baloni Szigetköz (n=30;*n=29)			*Gymnocephalus cernuus* Szigetköz (n=30)					
	M ± m	s		M ± m	s	t	p	CD	
Standard length (mm)	78.80 ± 2.88	15.76		91.90 ± 2.89	15.85	3.21	0.01	0.41	
Spines in D	14.63 ± 0.11	0.61		13.50 ± 0.10	0.57	7.39	0.001	*0.95*	
Soft rays in D	11.60 ± 0.12	0.67		12.80 ± 0.13	0.71	6.69	0.001	*0.86*	
Spines in A	2.00 ± 0.00	0.00		2.00 ± 0.00	0.00	-	-	-	
Soft rays in A	5.83 ± 0.11	0.59		5.37 ± 0.09	0.49	3.33	0.01	0.43	
In % of Standard length									
Head length	33.02 ± 0.20	1.08		31.84 ± 0.23	1.27	3.85	0.001	0.50	
Body depth	29.85 ± 0.22	1.20		25.94 ± 0.21	1.13	12.97	0.001	**1.67**	
Caudal peduncle depth	8.14 ± 0.12	0.67		8.01 ± 0.06	0.35	0.97	-	0.13	
Body width	19.14 ± 0.24	1.32		16.64 ± 0.20	1.11	7.93	0.001	*1.03*	
Caudal peduncle width	4.32 ± 0.15	0.78		4.48 ± 0.08	0.42	1.01	-	0.14	*
Predorsal distance	32.44 ± 0.25	1.34		30.75 ± 0.14	0.75	6.04	0.001	*0.81*	*
Postdorsal distance	17.00 ± 0.29	1.56		18.48 ± 0.35	1.90	3.27	0.01	0.43	*
Preventral distance	36.12 ± 0.34	1.85		34.97 ± 0.25	1.35	2.76	0.01	0.36	
Preanal distance	66.82 ± 0.26	1.40		67.22 ± 0.34	1.87	0.93	-	0.12	
Distance of P-V	3.49 ± 0.15	0.81		3.22 ± 0.15	0.84	1.26	-	0.16	
Distance of V-A	30.70 ± 0.37	2.03		32.26 ± 0.39	2.16	2.88	0.01	0.37	
Base of A to anus	6.96 ± 0.22	1.21		6.83 ± 0.19	1.03	0.44	-	0.06	
Caudal peduncle length	21.18 ± 0.36	1.94		22.86 ± 0.31	1.72	3.53	0.001	0.46	*
Length of spinous D	37.81 ± 0.38	2.06		35.23 ± 0.30	1.63	5.36	0.001	*0.70*	*
Length of soft D	12.75 ± 0.34	1.85		15.54 ± 0.34	1.88	5.75	0.001	*0.75*	*
Depth of spinous D	19.90 ± 0.27	1.46		20.85 ± 0.24	1.29	2.68	0.01	0.35	
Depth of soft D	16.67 ± 0.18	0.97		15.35 ± 0.19	1.04	5.01	0.001	0.65	*
Length of A	11.93 ± 0.37	1.99		9.92 ± 0.27	1.45	4.45	0.001	0.59	*
Depth of AI	16.71 ± 0.28	1.49		16.70 ± 0.24	1.32	0.03	-	0.00	*
Depth of AII	15.87 ± 0.19	1.00		15.20 ± 0.22	1.23	2.29	0.05	0.30	*
Length of V	22.35 ± 0.21	1.16		21.58 ± 0.21	1.17	2.58	0.02	0.33	
Length of P	21.04 ± 0.22	1.19		20.45 ± 0.17	0.93	2.16	0.05	0.28	
Length of C	16.98 ± 0.42	2.28		17.06 ± 0.33	1.80	0.15	-	0.02	
Diameter of DI	1.18 ± 0.02	0.13		1.07 ± 0.02	0.12	3.58	0.001	0.46	
Diameter of AI	1.94 ± 0.05	0.26		1.82 ± 0.06	0.31	1.57	-	0.20	
Diameter of VI	1.06 ± 0.02	0.11		0.97 ± 0.04	0.20	2.00	0.05	0.27	
Length of VI	13.75 ± 0.15	0.83		13.51 ± 0.37	2.02	0.61	-	0.09	
Length of V's base	5.62 ± 0.10	0.53		5.16 ± 0.11	0.59	3.20	0.01	0.41	
Length of P's base	6.08 ± 0.09	0.49		5.26 ± 0.12	0.64	5.56	0.001	*0.72*	
In % of Head length									
Head depth	64.24 ± 0.56	3.07		59.66 ± 0.78	4.27	4.77	0.001	0.62	
Head depth at eye	56.47 ± 0.54	2.91		52.79 ± 0.47	2.60	5.11	0.001	0.67	*
Head width	55.20 ± 0.44	2.36		51.59 ± 0.60	3.30	4.82	0.001	0.64	*
Diameter of eye	28.78 ± 0.29	1.61		26.61 ± 0.37	2.01	4.61	0.001	0.60	
Length of upper jaw	21.07 ± 0.35	1.93		20.46 ± 0.45	2.47	1.07	-	0.14	
Mouth width	38.28 ± 0.38	2.09		34.45 ± 0.44	2.38	6.62	0.001	*0.86*	
In % of AII's length									
Depth of the cut in the membrane between AI and AII	38.50 ± 1.11	6.08		13.28 ± 1.08	5.93	16.13	0.001	**2.10**	

3. Number of opercular spines is:
   * 2 = *G. baloni*
   * 1 = *G. cernuus*

   (after Holcik & Hensel 1974, Sivkov 1985).
   This character is extremely useful, as it can be seen even when investigating stomach contents of predatory fish.
4. Body depth (after Holcik & Hensel 1974, Sivkov 1985).
   This characteristics usually separates the two species very well (*G. baloni* has a larger relative body depth) with a reliability of 90-96% (CD = 1.28-1.75).
5. Number of praeopercular spines is:
   * 12-13 = *G. baloni*
   * 8-11 = *G. cernuus*

   (after Botta *et al.* 1984).
   This characteristic is of no use, as our results show a great overlapping: 9-14 in *G. baloni* and 8-11 in *G. cernuus* (see Holcik & Hensel 1974, Sivkov 1985).
6. The form of the soft membrane connecting two rays in the anal fin is:
   * deeply notched = *G. baloni*
   * barely notched = *G. cernuus*

   (after Botta *et al.* 1984, Pintér 1989).
   This peculiarity is of no use when working with improperly stored specimens, in which the membrane separates itself, and with fluid-preserved materials. In other instances it is a reliable character. According to our studies, the difference in notching at the AII (its extent as expressed in % of the AII-length):
   * *G. baloni* = 40.93±8.21 (Háros); 38.50±6.08 (Szigetköz)
   * *G. cernuus* = 12.61±7.74 (Háros); 13.28±5.93 (Szigetköz)

   $t = 13.75$; $p<0.001$; CD = 1.78 (Háros)
   $t = 16.13$; $p<0.001$; CD = 2.10 (Szigetköz).
   So this key character can be used with 97-99% reliability.

Habitat

Gymnocephalus baloni

The occurrence of *G. baloni* in the area under concern was, with one or two exceptions, restricted to the littoral zone. Eight individuals were found among submerged tree trunks, six juvenile and two adult specimens were recovered on a sandy or gravel bottom. The littoral region in the Háros section consisted of two transverse rode-fills and additional rock fills on the shore line with a length of 30 and 100 m, respectively. The same littoral habitat in the Szigetköz area consisted of cross dams isolating the side arms from the main arm. From our collectings we can assume that this species prefers extensive cover. *G. baloni* occurs either solitarily, or in pairs during the breeding season. In the vegetative period only occasional aggregations could be observed (for instance during critically low water levels).

The species exhibits a dual adaptation to flow characteristics. In the vegetative period, it requires high water velocity. Maximal occurrence was observed at 8.9±4.0 cm/s velocity. In this period it could not be observed in areas without current (Fig. 2). In and prior to the generative period (mostly from the end of March to mid-May) a balanced distribution of 1-2

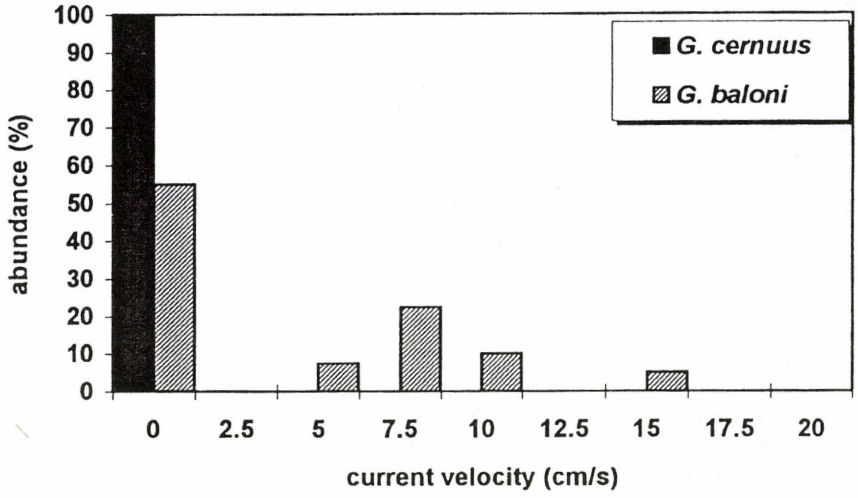

Fig. 1. The effect of the current on the abundance of *Gymnocephalus baloni* and *G. cernuus* in spawning time.

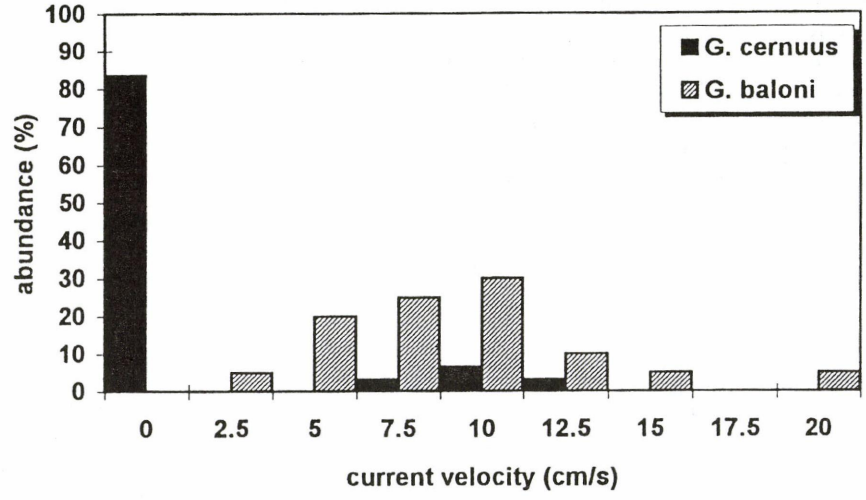

Fig. 2. The effect of the current on the abudance of *Gymnocephalus baloni* and *G. cernuus* out of spawning time.

m^2/pair could be observed in the littoral region. At the same time standing waters were also occupied, but another peak in occurrence could be seen at 7.5 cm/s. (Fig. 1).

During our collectings (apart from the breeding season, when it was also found on muddy substrate) it could usually be recorded from rocky shores with hollows, and occurred less abundantly on hard sand, clay and gravel bottom.

The spawning of this species is most intense from mid-April to the end of May. From the end of May until early June some spawning could be observed, though only in flowing areas.

Besides the so far published habitats, *G. baloni* was also found in the rivers Szamos, Mura and Túr.

Gymnocephalus cernuus

The occurrence of *G. cernuus* was characteristic in areas with an open bottom. This habitat consisted of the area between and beyond the two transverse rode-fills in the Háros section, and of the open sections between the cross dams in the Szigetköz. Some exceptions were seen during and before the breeding season. In this period, from March to April, *G. cernuus* individuals could be observed in large numbers in the shallow littoral region with no water current. Both in the vegetative, as well as in the generative season, the occurrence of this species was group-wise. In an individual school, three to four age classes were present, but usually there was one dominant age group.

G. cernuus could mostly been observed in areas with no water current (Figs 1, 2). However, in some occasions, feeding schools moved into whirly areas behind rode-fills. As regards substrate type, this species could be found both on gravel, sand and clay bottom, as well as on muddy substrate. In the Háros section, it preferred muddy, sandy bottom to other types.

The spawning of *G. cernuus* lasted from early April to the beginning of June in the areas under concern, and took place primarily in the shallow water at the rock fills of the shore line.

Growth

Gymnocephalus baloni

Studies of the growth of *G. baloni* have not yet been published. According to our investigations, it is a slowly growing species, reaching 12-13 cm average length at the age of 7 years. Growth is the most intense in the first year (31-32 mm), increases evenly during the second to fourth summer (15.5-18.2 mm/year), and slowly decreases afterwards, amounting 7-12 mm annually in the sixth and seventh year of age (Table 3, Figs 3, 4).

The growth of the *G. baloni* populations is statistically similar in both habitats investigated with the exception of age group 0^+ ($p<0.05$ in favour of the Háros population). Growth of *G. baloni* at Háros can be described by Bertalanffy's curve L_t (cm) = $19.4\ (1\text{-}e^{-0.133\ (t\ +\ 0.297)})$, and in the Szigetköz by L_t (cm) = $23.4\ (1\text{-}e^{-0.096\ (t\ +\ 0.514)})$.

Body length/body mass relations were determined on the basis of samples collected in 1993. Significant differences were found between the two habitats (see also Specziár 1995):

lgw = 3.48 lgL – 5.51 (R^2 = 0.96, n = 50) (Háros)

lgw = 2.91 lgL – 4.43 (R^2 = 0.97, n = 31) (Szigetköz).

No statistically significant differences could be found between the growth of males and females. However, males reached a somewhat larger size in all age groups in both habitats.

Gymnocephalus cernuus

This species is also slowly growing, reaching 32-36 mm body length in the first year of age in the Danube. 6-8 years are needed to attain 12-13 cm body length. Growth slows after the first year. It is more or less even in the second to fifth year (14.8-19.7 mm/year), but strongly

Table 3. The growth of *Gymnocephalus baloni* and *G. cernuus* in the Danube – back counted data.

	Gymnocephalus cernuus											
	Háros					Szigetköz						
age	body length			weight		growth	body length			weight		growth
(years)	(mm)	±	s	(g)	± s	(mm)	(mm)	±	s	(g)	± s	(mm)
0+	32.7	±	3.0	0.7	± 0.3	32.7	36.0	±	3.0	0.8	± 0.2	36.0
1+	49.4	±	5.0	2.6	± 0.7	16.7	55.7	±	5.6	3.4	± 1.1	19.7
2+	65.5	±	6.0	6.2	± 1.8	16.1	73.0	±	5.8	7.8	± 1.9	17.3
3+	80.7	±	6.8	11.2	± 3.1	15.2	90.1	±	6.9	14.8	± 3.7	17.1
4+	95.5	±	7.2	19.9	± 4.7	14.8	106.3	±	4.1	23.5	± 4.4	16.2
5+	105.7	±	7.8	27.3	± 6.3	10.2	118.7	±	5.5	30.2		12.4
6+	114.8	±	5.1	35.3	± 5.1	9.1	121.7			40.1		3.0
7+	122.0	±	3.6	42.6	± 4.4	7.2						
8+	129.2			51.0		7.2						
9+	137.5			61.0		8.3						

	Gymnocephalus baloni											
	Háros					Szigetköz						
age	body length			weight		growth	body length			weight		growth
(years)	(mm)	±	s	(g)	± s	(mm)	(mm)	±	s	(g)	± s	(mm)
0+	32.2	±	3.1	0.6	± 0.2	32.2	31.2	±	2.6	0.7	± 0.2	31.2
1+	49.8	±	4.5	2.5	± 0.5	17.6	49.4	±	4.4	2.7	± 0.8	18.2
2+	67.7	±	6.2	7.3	± 2.3	17.9	66.7	±	5.8	7.0	± 2.0	17.3
3+	84.5	±	6.3	15.8	± 4.1	16.8	82.2	±	6.5	12.7	± 2.7	15.5
4+	97.5	±	5.6	25.9	± 5.2	13	95.9	±	6.4	22.1	± 3.0	13.7
5+	111.9	±	7.7	41.9	± 10.0	14.4	108.8	±	6.9	25.5		12.9
6+	119.3	±	5.2	52.3	± 8.0	7.4	120.1	±	6.4			11.3
7+	127.7			65.5		8.4	132.5					12.4

decreases afterwards. In the seventh to eighth year of age only 3-8 mm annual growth could be observed.

When comparing the two populations of *G. cernuus* one can conclude that conditions for growth were more favourable in the Szigetköz branch system than at Háros (t-test values $p<0.001$ for ages 0^+ to 4^+, whereas $p<0.05$ for age group 5^+). Our measurements are to be found in Table 3, and in Figs 3, 4.

Growth of *G. cernuus* at Háros can be described by Bertalanffy's curve L_t (cm) = 19.4 $(1\text{-}e^{-0.121\ (t\ +\ 0.503)})$, and in the Szigetköz by L_t (cm) = 25.7 $(1\text{-}e^{-0.095\ (t\ +\ 0.567)})$.

Body length/body mass relations were determined on the basis of samples collected in 1993:

lgw = 3.11 lgL – 4.86 (R^2 = 0.98, n = 51) (Háros)

lgw = 3.13 lgL – 4.96 (R^2 = 0.98, n = 37) (Szigetköz).

Growth of males and females was statistically similar, except for age group 5^+ at Háros, in which males proved to be larger ($p<0.05$).

Feeding

Gymnocephalus baloni

The food of *G. baloni* was already investigated by Nagy (1985, 1986) in the Csallóköz section of the Danube. The results of our examinations of the food composition in this species are shown in Figs 5a and 5b.

The food of this species was more varied (D = 1.58) in the Háros section than in the Szigetköz area (D = 0.93). The dominant food in both areas were chironomid larvae (and pupae). Besides, the proportion of leeches (*Herpobdella octoculata, Helobdella stagnalis*) was significant at Háros, particularly considering their size. The role of snails, web-building

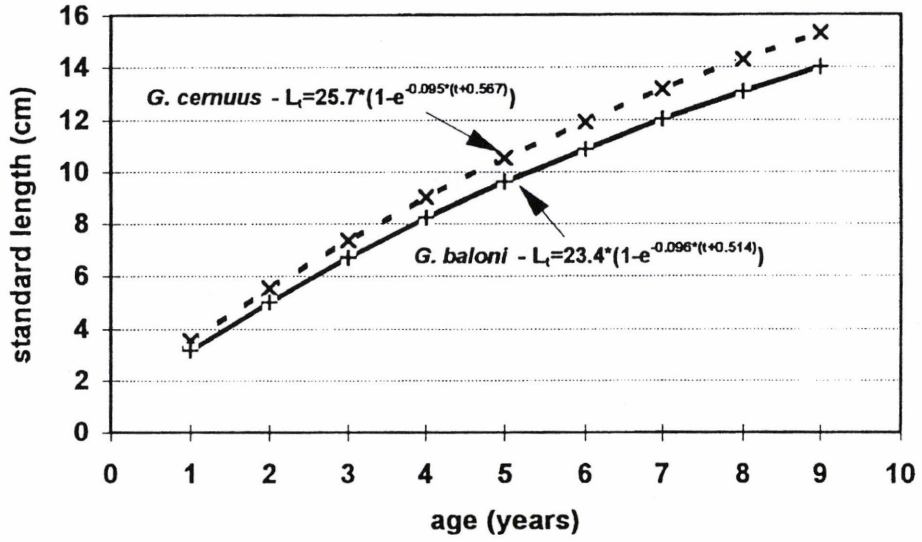

Fig. 3. The growth of *Gymnocephalus baloni* and *G. cernuus* in the Szigetköz side-branch system near Ásványráró – Bertalanffy's curves.
L_t is the standard body length (cm) and t is the age (in years).

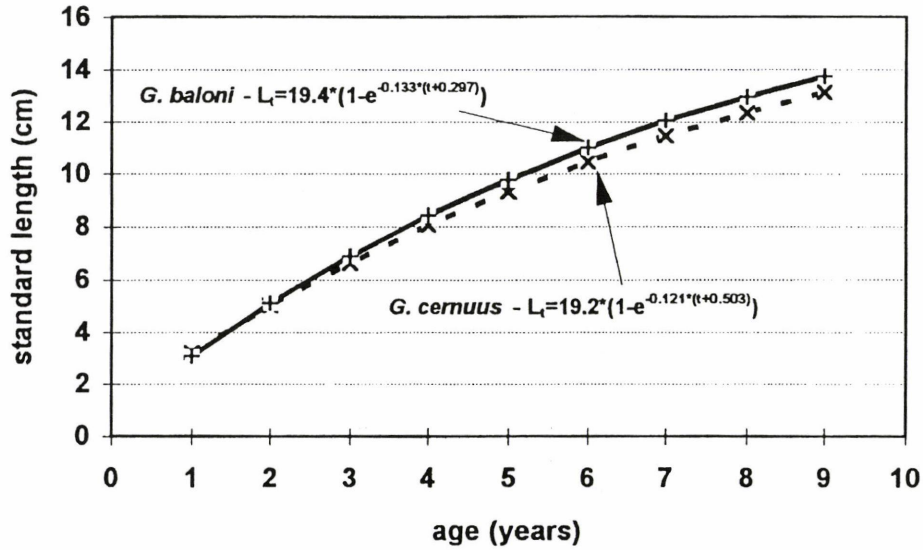

Fig. 4. The growth of *Gymnocephalus baloni* and *G. cernuus* in the middle section of the Danube at Háros (Budapest) – Bertalanffy's curves.
L_t is the standard body length (cm) and t is the age (in years).

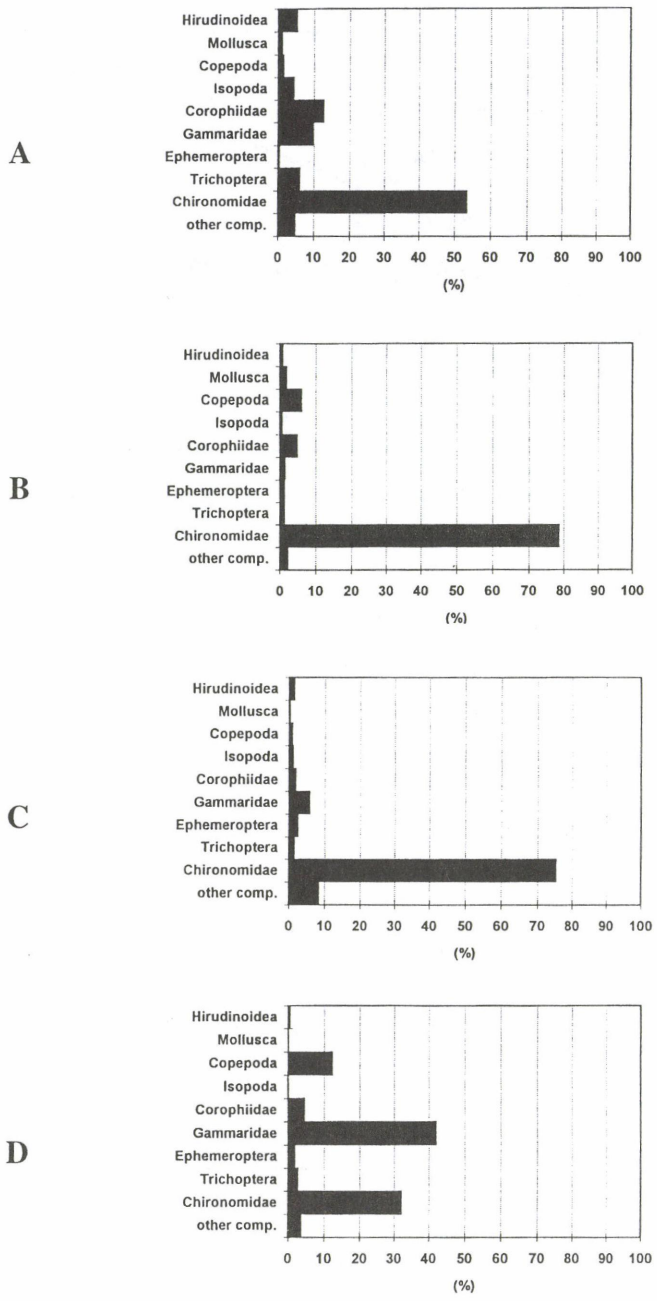

Fig. 5. The food composition of *Gymnocephalus baloni* and *G. cernuus* in the Danube. A = *G. baloni* at Háros; B = *G. baloni* in the Szigetköz side-branch system; C = *G. cernuus* at Háros; D = *G. cernuus* in the Szigetköz side-branch system

caddisflies and crustaceans (Isopoda, Corophiidae, Gammaridae) in the food of this species is considerable. In the Szigetköz area, on the contrary, the role of other groups in the food other than chironomid larvae is much less significant (C_N= 0.56; $p<0.001$ in the χ^2-test). Only clams (*Pisidium* sp.) and *Corophium curvispinum* can be mentioned in this respect.

The food contained plant matter in very small quantities in both areas under concern. In spring, occasionally fish eggs, and in one instance in the Szigetköz area even a fish (*Proterorhinus marmoratus*) could be found.

The composition of the food changed strongly during the year in both areas. While a gradual reduction in the proportion of chironomid larvae (from 63.5% to 39.1%) in favour of amphipods (from 14.4% to 42.5%) could be observed in the Háros section, an increase in the proportion of chironomid larvae (59.0% to 91.9%) became apparent in the Szigetköz.

Gymnocephalus cernuus

The food composition in *G. cernuus* is shown in Figs 5c and 5d. Significant differences were found between the two habitats also in this species (C_N= 0.43; p<in the χ^2-test).

The food consumed was more varied (D= 1.45) in the Háros section. It consisted mainly of chironomid larvae and pupae, and gammarids. Besides, in smaller amounts also *Corophium curvispinum*, ephemeropteran and trichopteran larvae were found. Although the number of cyclopid specimens in the samples was considerable, their overall role in the food mass is negligible. The proportion of leeches is similarly insignificant; segmented worms have been found in a few instances only, while gastropods are lacking entirely.

By contrast, the main component in the food of *G. cernuus* in the Szigetköz area were chironomid larvae and pupae (D = 1.01). The proportion of other food components is well-balanced, but extremely small. This species consumes also fish eggs in spring.

The changes observed in food components were similar at both sampling sites. The proportion of chironomid larvae strongly increased in summer, that of *Corophium curvispinum* in spring and autumn. With the exception of the summer period, when a significant dwindling of the food basis (D = 0.50) could be observed, the results of our investigations in the Szigetköz during 1993 were similar to those described by Nagy (1985) for the Csallóköz area. Elsewhere, the food of *G. cernuus* may be of entirely different composition.

Discussion

We found several ecological and ethological differences between *G. baloni* and *G. cernuus* originally separated on a morphological basis. Most important of these is the divergence in habitat, as this probably explains most of the differences found. For further investigation, a more detailed study of the deep- and shallow-bodied morphs of *G. cernuus* described from the Dneiper (Aleksandrova 1974) could be of possible help.

From the determinating characters, we suggest to use at least one more character (e.g. the degree of notching at the AII) in addition to coloration features, when working in the field. When working in the laboratory, we recommend to use as many reliable characteristics as possible. Recently conducted morphological studies (Kovac 1993a, b) may serve as a basis for separating the two species in their early stages of ontogeny.

Based on our investigations, we concur with Holcik & Hensel (1974) and Botta *et al.* (1984) that *G. baloni* is bound to hiding-places located in flowing waters, so it is mostly found at

rock fills in the Danube. A further proof could be for its reophilous pattern that self-sustaining populations of this species have never been reported from lakes or other standing water bodies. It has been published only from the Danube and its side rivers (Holcik & Hensel 1974, Hensel 1979, Botta *et al.* 1984, Harka 1984, Guelmino & Harka 1985, Sivkov 1985, Keresztessy 1993, Harka 1992a, b). Also the body pattern serves as an adaption to this habitat. Its body shape, the robust and deep body, stronger fin rays, etc., can probably be related to its habits rather than directly to its habitat. *G. baloni* leads a solitary life, and is found in aggregations only when conditions are suboptimal. Botta *et al.* (1984) assumed that *G. baloni* was a territorial species spawning in pairs. This behaviour is common in the family Percidae. Since we observed the dispersion of the population during the breeding season, and that less favourable habitats without current were also occupied in this period, we can conclude that territorial behaviour is increasing at these times. Since *G. baloni* occurs in pairs at this time the spawning in pairs is also probable. Territorial behaviour, when existing, is less apparent in the vegetative period. Further studies are required in order to gain a better understanding of its habits, which have to include observations and tests of captive individuals as well.

According to our investigations, the habitats of the two species differ considerably. Some overlapping could be observed in the Háros section in the breeding season only. In this period, *G. baloni* and *G. cernuus* co-occurred in the shallow water at the rock fills of the shore line, in a proportion of 11 to 2 on average (varying between 14:1 and 2:7), in favour of *G. cernuus*. No overlap was found in the Szigetköz area under concern.

The situation observed at Háros can probably be explained by the lack of both suitable habitats as well as spawning areas. Such areas include the river sections regulated by transverse rode-fills, which have a muddy shore. The possibility of hybridisation in such a shared habitats is probably reduced by the considerably different social behaviour of the two species (territoriality – group-wise occurrence). For the occurrence of the two species in and outside the breeding season see Figs 1 and 2, respectively. (For a comparison of breeding biology in both species see the work of Bastl [1988]).

The growth of *G. cernuus* has been studied by many authors. In Hungary, its growth in Lake Balaton (Bíró 1971) is less intense than that observed for the Danube. Elsewhere, e.g. in certain areas of Siberia, it grows at a considerably faster rate (Kolomin 1977).

Growing capacity of the two species as expressed in body length is probably similar. The differences observed have to be related to the characteristics of the two sampling sites. With the exception of age group 3^+, no significant difference could be found at Háros, where *G. baloni* proved to reach a larger size ($p<0.02$). In the Szigetköz area, however, the two species exhibited a different growth pattern. Here, growth of *G. cernuus* was more intense ($p<0.001$ for age group 0^+-4^+, and $p<0.05$ for 5^+).

In Hungary, the food of *G. cernuus* has exclusively been studied in Lake Balaton (Tölg 1960, Ponyi *et al.* 1972). According to Fedorova & Vetkasov (1974), and Kozlova & Panasenko (1977), older specimens started to lead a semi-predatory life, whereas Leszczynski (1963) observed a strong specialisation of adult individuals (these preyed upon mostly 2-3 species only), and consumed larger amounts of fish eggs (Fedorova & Vetkasov 1974, Pavlovskiy & Sterligova 1986).

As regards food composition, specific differences can also be found besides those that may be explained by differences in habitat. This is more pronounced at Háros ($C_N = 0.53$; $p<0.001$ in the χ^2-test), and less so in the Szigetköz ($C_N = 0.76$; $p<0.001$ in the χ^2-test). Leeches, gastropods and crustaceans play a more important role in the food of *G. baloni* than in that of *G. cernuus*, particularly at Háros. *G. baloni* also consumed a larger amount of trichopterans

and chironomid larvae, primarily in autumn. On the other hand, the food of *G. cernuus* contains more gammarids and copepods. In addition, an increasing consumption of corophiids by *G. cernuus* could be observed in summer, when this component was entirely lacking in *G. baloni*. Smaller differences were found between the two species in the Szigetköz area, although *G. baloni* consumed larger amounts of gastropods (*Pisidium* sp.) and corophiids annually, whereas gammarids dominated in *G. cernuus*. Similar to the results of research conducted in the Csallóköz (Nagy 1985, 1986), the food of the two species significantly differed only on the species level and in the proportion of the various components. These differences can best be explained by differences in habitat. So *G. baloni* inhabiting rock-fills consumes more leeches, gastropods, etc. than *G. cernuus*, which searches for food on the open bottom.

Even Holcik & Hensel (1974) presumed that the separation of the two species could possibly be explained by their ecological isolation. On the basis of the results of our investigations, we conclude that the separation of habitats was the first step within the process of ecological isolation that triggered further changes in ethology (solitary life, territorial behaviour in contrast to group-wise occurrence) and morphology (the selection of the deep-bodied *G. baloni* for stronger territoriality).

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